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# Evaluation of salinity tolerance in fourteen selected pistachio (*Pistacia vera* L.) cultivars

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*Key words*: chlorophyll fluorescence, Ghazvini cultivar, growth indices, *Pistacia vera* L., salinity water.



**Abstract: Cultivars and rootstocks tolerant to salinity are determinant to increase the salt tolerance of planted fruit trees including pistachio. In this research, the effect of salinity stress on morphological and physiological traits as well as the concentration of nutrition elements in some pistachio cultivars was investigated based on completely randomized design (CRD), with two factors cultivars and irrigation water salinity. Studied cultivars were Ghazvini, Shahpasand, Akbari, Khanjari, Jandaghi, Italiyayi, Fndoghi 48, Sabz Pesteh Tohg, Ahmad Aghaee, Rezaie Zood Res, Mousa Abadi, Ebrahimi, Kaleh Ghochi and Badami Zarand and levels of salinity were 0.5, 4.9, 9.8, 14.75 and 19.8 dS/m. Each treatment had nine replicas. The results showed that increasing salinity reduced branch height, branch diameter, number of total leaves, and percentage of green leaves, relative humidity content, chlorophyll a, chlorophyll b and total chlorophylls in all cultivars. But percentage of necrotic leaves, percentage of downfall leaves, relative ionic percentage and cell membrane injury percentage were increased. The results showed that salinity stress affected the young trees through increasing the amount of minimum fluorescence ($F_0$) and decreasing the maximum fluorescence ($F_M$) and reducing variable fluorescence ($F_V$) as well as the ratio of variable fluorescence to maximum fluorescence from 0.83±1 in the control plants to 0.59±0.015 in Rezaie Zood Res cultivar and 0.61±0.009 in Mousa Abadi cultivar. The results also showed that in the total cultivars studied, the highest amount of $Na^+$ in leaves and roots (2.09±0.04% and 3.04±0.06%), and the lowest amount of $K^+$ in leaves and roots (0.40±0.02% and 0.34±0.01%), were observed in treatment 19.75 dS/m. Overall, Ghazvini was found to be the most tolerant cultivar to salinity stress. This cultivar could well tolerate salinity 14.75 dS/m.**

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All relevant data are within the paper and its Supporting Information files.

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The authors declare no competing interests.

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## 1. Introduction

Pistachio (*Pistacia vera* L.) is one of the important commercial crops in Iran. Majority of pistachio orchards are located in areas with saline soil and are irrigated with low quality and salty waters. Although pistachio trees are classified as tolerant to salinity, researches have demonstrated that growth rates of pistachio trees decrease with increasing sodium chloride (NaCl) concentration in soil and there is a positive correlation between sodium ($Na^+$) as well as chloride ($Cl^-$) concentration in plant tissue and soil (Sepaskhah and Maftoun, 1988; Noitsakis *et al*., 1997; Munns and Tester, 2008; Zrig *et al*., 2015). Salinity stress also negatively affects photosynthesis rate, morphology of leaves, and nutrient balance in pistachio trees (Picchioni and Myamoto, 1990; Saadatmand *et al*., 2007; Karimi *et al*., 2011). Walker *et al*. (1987) and Karimi *et al*. (2009) reported that the highest chloride concentrations were observed in lamina and petiole of pistachio seedlings irrigated with salty water, whereas highest sodium concentration was observed in roots. Ferguson *et al.* (2002) suggested that the decrease of water potential in plant in higher salinity levels is one of the main reason for decrease pistachio yield.

It has been reported that salinity stress is one of the most important environmental factors limiting photosynthesis in the majority of worldwide cultivated crops, including pistachio crop (Maxwell and Johnson, 2000; Ranjbarfordoei *et al*., 2006). Chlorophyll fluorescence (CF) has been used to study plant responses to different kinds of stress (Baker and Rosenqvist, 2004). Chlorophyll (Chl) fluorescence yield (Chl FY) such as minimal Chl FY ($F_0$) and variable Chl FY ($F_v$) can be used for evidencing stress and damage of the photosynthetic apparatus, and characterizing the environment where plants grow (Herda *et al*., 1999; DeEll and Toivonen, 2003; Kodad *et al*., 2010). $F_v/F_m$ ratio has been used in many studies related to stress in plants. In most of plants, when ratio $F_v/F_m$ is around 0.83 means that stress has not been introduced to the plant. Values lower than this will be seen when the plant has been exposed to stress, indicating in particular the phenomenon of photo inhibition (Herda *et al*., 1999; DeEll and Toivonen, 2003; Kodad *et al*., 2010).

Selecting nutrient sources that do not add harmful ions and salinity to irrigation water to avoid compounding salinity problems would be the best option. In areas affected by soil and water salinity, nevertheless, it is more convenient to use salt-tolerant rootstocks for the species characterized by a certain degree of salt tolerance, i.e. *Pistacia* sp. An important characteristic of *Pistacia* sp. is their ability to store large quantities of $Na^+$ in roots, which might make pistachio tolerant to $Na^+$ (Picchioni and Myamoto, 1990; Karimi *et al*., 2011). Sepaskhah and Maftoun (1988) reported that 50% reduction in shoot growth was observed when the average root-zone salinity was between 7.9 and 10 dS/m (ECe). Saadatmand *et al.* (2007) postulated that salinity stress had more negative influence than drought stress on pistachio growth. They reported that Sarakhs variety showed higher sensitivity to soil salinity than Qazvini variety, but with increasing in irrigation intervals, Sarakhs was more-tolerate to salinity than Qazvini.

Although, other researchers have studied the influence of soil and water salinity on the growth indices and chemical composition of pistachio cultivars, but in before researches a low number of cultivars was investigated. Therefore, in this research, the effects of five levels of irrigation water salinity on morphological and physiological traits as well as the concentration of nutrition elements in fourteen selected pistachio (*Pistacia vera* L.) cultivars have been investigated in order to find most tolerant cultivars to salinity.

## 2. Materials and Methods

*Plant material and natural salt treatments*

In this research, the effects of salinity stress on morphological and physiological traits and on the concentration of nutrition elements in 14 pistachio cultivars such as Ghazvini, Shahpasand, Akbari, Khanjari, Jandaghi, Italiyayi, Fndoghi 48, Sabz Pesteh Tohg, Ahmad Aghaee, Rezaie Zood Res, Mousa Abadi, Ebrahimi, Kaleh Ghochi and Badami Zarand were investigated. The experiment was carried out in the research greenhouse of Temperate Fruit Research Center, Horticultural Research Institute in Karaj-Iran in years of 2013 and 2014 based on completely randomized design (CRD), with two factors; cultivars with 14 levels and irrigation water salinity by 5 levels (Control= 0.5 dS/m, A= 4.8 dS/m, B= 9.8 dS/m, C= 14.75 dS/m and D=19.8 dS/m) and with nine replications for each treatment, for a total of 630 pots. Seeds were germinated according to the method described by Karimi *et al.* (2009). Seeds were pretreated with benomyl (wettable powder-50%; DuPont, Wilmington, DE, USA) for 24 h, and then incubated at 30°C within layers of sterile moist crisped cloth. After radicle emergence, seeds were planted in Jiffy pots (Jiffy Group, Moerdijk, Netherlands) and grown in a greenhouse for three months. Seedlings with 10 to 15 cm height were transplanted to pots 2 Kg filled with soil series of fine loamy mixed, which its characteristics are listed in Table 1.

Salinity treatment was started and continued for

Table 1 - Physical and chemical characteristics of soil mixture

| Title | Value |
|---|---|
| Saturation percentage (%) | 39 |
| Field capacity (%) | 27.33 |
| Permanent wiltering point (%) | 14.8 |
| dS/m (EC) | 1.28 |
| pH | 7.5 |
| N (%) | 0.15 |
| Organic carbon (%) | 1.49 |
| P (ppm) | 104.9 |
| Sand (%) | 46 |
| Silt (%) | 34 |
| Clay (%) | 20 |
| Texture | Loam |
| Ca (ppm) | 1230 |
| Mg (ppm) | 316.2 |
| Total neutralizing value (%) | 13.8 |
| Cu (ppm) | 2.12 |
| Zn (ppm) | 4.86 |
| Fe (ppm) | 27.34 |
| K (ppm) | 690 |
| Mn (ppm) | 16.26 |
| Na (ppm) | 93.15 |

two and half months. For salinity treatments, salts were collected of salt lake shore in Qom-Iran. Then, salinity treatments were obtained by solving 0, 2.4, 4.8, 7.2 and 9.6 g of salt in 1 L of water (treatments composition is reported in Table 2). Also, to avoid sudden shock and plasmolysis, salt treatments were gradually added and reached to the final concentration within a week (2 stages of irrigations). Field capacity (FC) of soil in pots was determined before transferring plants to units by a pressure plate (Model F1, make USA). Irrigation schedule was organized according to pots changes in weight and leaching requirement. Electric conductivity and pH rate were regularly measured in drainage water to maintain the electric conductivity of both input and soil solutions in a stable range. At the end of the experiment, the soil of pots in each level salinity was mixed together. Then three samples of each treatment (in total 15 samples) were analyzed (Table 3).

*Growth parameters*

At the end of the experiment, growth characteristics including main-shoot length, trunk diameter and number of leaves, were measured as well as percentage of necrotic leaves, downfall leaves and green leaves were calculated (Papadakis *et al*., 2007). Fresh weight of leaves, main-shoots and roots were measured immediately after removing, using a digital scale. Dry weight of the samples was measured using an oven at 75°C for 48 h (Papadakis *et al*., 2007).

*Physiological parameters*

For determination of leaf chlorophyll, 0.2 g of leaf was extracted (in total 630 samples, means nine replicas for each cultivar and for each salinity treatment), with ethanol 80% and chlorophyll *a*, chlorophyll *b* and total chlorophyll content were calculated with the method described by Arnon (1949). Leaf greenness (chlorophyll index) was evaluated on the same leaves used for gas exchange and fluorescence using a SPAD (Minolta, 502, made in Japan) after 75 days since treatments introduction.

Leaf relative water content (RWC) was determined with nine replicas (made by four leaves each) for each treatment and for each cultivar, for a total of 630 samples. Fresh weight (Fw) was recorded and then samples were put into distilled water and kept at 4°C for 24 h in the dark. After the emission of extra humidity, samples were weighed again to obtain the Total weight (Tw). Subsequently, samples were kept in the oven at 105°C for 24 hours and Dry weight (Dw) was recorded. Finally, relative water content was calculated via formulae (Yamasaki and

Table 3 - EC and pH soil treated with different levels of salinity

| Treatments | EC (dS/m) | pH |
|---|---|---|
| Control | 1.2 | 7.4 |
| A | 5.7 | 7.65 |
| B | 10.9 | 7.87 |
| C | 15.95 | 7.96 |
| D | 21.3 | 8.05 |

Table 2 - Salt solution characteristics

| Treatments | Electrical conductivity (dS/m) | (pH) | Na (mg/L) | Cl (mg/L) | Ca (mg/L) | Mg (mg/L) | $HCO_3^-$(mg/L) |
|---|---|---|---|---|---|---|---|
| Control | 0.50 | 7.30 | 22.1 | 35.5 | 62 | 17.1 | 98 |
| A | 4.90 | 7.60 | 809 | 1386 | 79 | 23.01 | 137 |
| B | 9.80 | 7.78 | 1653 | 2836 | 99 | 25.7 | 159 |
| C | 14.75 | 7.87 | 2443 | 4199 | 123 | 28.5 | 186 |
| D | 19.80 | 7.95 | 3276 | 5610 | 151 | 31.9 | 214 |

Dillenburg, 1999).

$$RWC= [(Fw-Dw) / (Tw-Dw)] \times 100$$

For the determination of relative ionic content was determined with nine replicas (made by four leaves each) for each treatment and for each cultivar, for a total of 630 samples. The amount of 0.5 g of each sample was put in tubes with 25 ml of distilled water at 25°C for 24 h on a shaker with speed 120 in/min. Electrical conductivity (EC) of the medium was then read using a conductivity meter (conduct meter; Radiometer, Copenhagen). Following the initial reading (Lt), samples were autoclaved for 20 min to kill leaf tissues and then kept at 25°C for 2 h on shaker with speed 120 in/min and a final reading (Lo) was obtained. Finally, relative ionic percentage was calculated via formulae:

$$\text{Relative ionic percentage} = (Lt/Lo)/100$$

as described in Lutts *et al.* (1995).

After calculation relative ionic percentage, cell membrane injury in samples' treatment with natural salt ratio samples control was performed as follows:

$$\%\ Injury = 1- [1- (T1/T2)/ 1- (C1/C2)] \times 100$$

Where T and C refer to the EC values of stress-treated and control tubes and 1 and 2 refer to the initial and final EC, respectively (Lutts *et al*., 1995).

*Chlorophyll fluorescence parameters*

Chlorophyll fluorescence of leaves was measured using a portable fluorometer *PAM-2000* (H. Walz, Effeltrich, Germany). Before measuring chlorophyll fluorescence parameters, three leaves on main-branch of each plant were put in dark-adapted state (DAS) for 30 min using light exclusion clips (Maxwell and Johnson, 2000). Maximum quantum efficiency of photosystem II ($F_v/F_m$) was determined as $F_v/F_m= (F_m-F_0)/F_m$; where $F_m$ and $F_0$ were maximum and minimum fluorescence of dark-adapted leaves, respectively.

*Concentration of $Na^+$ and $K^+$*

Concentration of $Na^+$ and $K^+$ in leaves and roots was determined with nine replicas for each treatment and for each cultivar, for a total of 630 samples. Leaves and roots of each plant, oven-dried at 75°C for 48 h, and then milled to a fine powder to pass through a 30-mesh screen. The amount of 0.5 g of each sample was dry-ached for 6h at 550°C, dissolved in 3 mL of 6 mol $L^{-1}$ HCl and diluted to 50 mL with deionized water. Subsequently, concentration of $Na^+$ and $K^+$ were determined using atomic absorption spectroscopy (Papadakis *et al*., 2007).

*Statistical analysis*

This experiment was carried out based on completely randomized design (CRD), with factors cultivars in 14 levels and irrigation water salinity in 5 levels and with nine replicas for each treatment in research greenhouse of Temperate Fruit Research Center, Horticultural Research Institute in Karaj-Iran in years 2013 and 2014. Finally, data were analyzed using analysis of variance (ANOVA) using SAS software. Means were also compared by Duncan's Multiple Range test at 1% level.

## 3. Results

As reported in Table 4, salinity treatments negatively affected plant height, trunk diameter and number of leaves. With increasing salinity concentration in irrigation water, final height, trunk diameter and number of leaves in all studied cultivars were decreased. The lowest branch height, trunk diameter and leaf number were observed in salinity level D. The rate of decrease branch height, trunk diameter and number of leaves among the cultivars showed a significant difference with each other. The height of Khanjari, Jandaghi, Italiyayi, Fndoghi 48, Sabz Pesteh Tohg, Ahmad Aghaee, Rezaie Zood Res, Mousa Abadi, Ebrahimi and Kaleh Ghochi cultivars were decreased in salinity level B compared to control plants. While the height of Akbari, Shahpasand and Badami Zarand cultivars in salinity level C and in Qazvini cultivar only in salinity level D was decreased significantly compared to control plants.

As reported in Table 4, as the salt concentration increases, the trunk diameter and its growth were decreased during the application of salinity stress in all cultivars. The decrease in trunk diameter in the cultivars showed a significant difference with each other. The trunk diameter of Khanjari, Fndoghi 48, Rezaie Zood Res, Mousa Abadi and Kaleh Ghochi cultivars was decreased in salinity level B compared to control plants. While the trunk diameter of Italiyayi, Jandaghi, Ebrahimi, Sabz Pesteh Tohg, Ahmad Aghaee, Akbari, Shahpasand and Badami Zarand cultivars in salinity level C and in Qazvini cultivar only in salinity level D was decreased significantly compared to control plants.

The results showed that number of leaves with increasing salinity concentrations were reduced, but the amount of reduction in the number of leaves in different cultivars had significant differences. The maximum number of leaves were observed in control

Table 4 - Effect of interaction between salinity and cultivar on some of the morphologic traits

| Cultivars | Treatments | No. of green leaves | Green Leaves (%) | Trunk diameter (mm) | Branch height (cm) |
|---|---|---|---|---|---|
| Khanjari | Control | 27.33±1.0 h-n | 100.00±0.0 a | 8.38±0.13 a | 32.50±1.56 f-g |
| | A | 25.00±1.93 n-r | 100.00±0.0 a | 8.38±0.09 a | 31.47±0.37 g-j |
| | B | 22.55±1.42 s-v | 97.02±3.81 a-d | 8.07±0.09 b | 28.67±1.17 k-n |
| | C | 20.00±1.22 t-w | 76.21±5.82 m-o | 7.57±0.09 cd | 25.55±0.52 r-s |
| | D | 16.33±1.32 x-z | 51.41±6.87 q | 6.94±0.05 f-h | 21.31±0.54 w-x |
| Akbari | Control | 24.67±1.80 o-s | 100.00±0.0 a | 7.53±0.10 c-d | 25.05±2.78 r-s |
| | A | 22.89±0.78 s-u | 100.00±0.0 a | 5.55±0.09 c-d | 24.38±2.69 s-u |
| | B | 22.11±0.70 s-v | 100.00±0.0 a | 7.31±0.05 d-e | 23.55±1.26 s-v |
| | C | 18.45±0.72 u-y | 96.86±4.23 a-d | 7.14±0.06 e-g | 22.67±1.29 t-y |
| | D | 16.45±0.88 x-z | 89.43±4.92 g-i | 6.65±0.08 h-j | 20.18±1.79 w-y |
| Ghazvini | Control | 27.23±0.77 h-n | 100.00±0.0 a | 5.82±0.07 p-u | 22.57±1.08 t-w |
| | A | 27.07±0.26 i-m | 100.00±0.0 a | 5.81±0.07 p-u | 22.55±0.57 t-w |
| | B | 26.52±0.67 j-o | 99.55±0.0 a | 5.70±0.05 s-w | 21.67±0.50 u-x |
| | C | 25.77±0.67 m-r | 97.72±5.63 a-c | 5.46±0.04 u-x | 20.7±1.0 w-y |
| | D | 23.81±2.24 q-u | 90.88±7.07 e-h | 5.02±0.06 x-y | 18.11±1.21 y-z |
| Italiaie | Control | 31.67±2.34 e | 100.00±0.0 a | 6.71±0.03 h-j | 33.00±2.95 e-h |
| | A | 31.06±2.0 e-f | 100.00±0.0 a | 6.74±0.16 h-j | 32.30±1.21 f-h |
| | B | 29.22±1.39 f-i | 98.85±2.40 a-b | 6.53±0.12 j-m | 30.17±0.94 i-k |
| | C | 25.22±1.71 n-r | 90.72±8.49 e-h | 6.15±0.29 n-q | 26.43±1.19 o-r |
| | D | 22.33±2.34 q-u | 84.88±5.04 i-k | 5.60±0.24 t-x | 22.71±1.90 t-w |
| Kaleh Ghochi | Control | 27.00±1.93 i-n | 100.00±0.0 a | 6.63±0.05 f-h | 32.09±0.87 f-h |
| | A | 26.85±0.86 i-n | 10000±0.0 a | 6.59±0.04 j-k | 31.87±0.86 f-i |
| | B | 23.44±0.72 q-u | 97.66±3.04 a-c | 6.28±0.03 l-p | 28.87±0.86 k-n |
| | C | 19.33±1.0 u-w | 89.60±5.26 f-i | 5.78±0.04 p-u | 25.43±0.71 r-s |
| | D | 15.33±1.0 y-z | 72.92±7.64 o | 5.25±0.03 w-x | 20.28±0.48 x-y |
| Jandaghi | Control | 27.89±1.05 g-j | 100.00±0.0 a | 6.05±1 p-r | 23.56±0.73 s-v |
| | A | 27.11±2.26 i-m | 100.00±0.0 a | 6.04±1 p-r | 23.45± 1.05 s-w |
| | B | 25.33±0.70 n-r | 95.80±3.46 a-e | 5.97±1 q-s | 21.03±0.53 w-x |
| | C | 20.67±1.93 t-w | 80.96±6.21 k-m | 5.33±1 u-x | 18.73±0.68 y-z |
| | D | 15.44±1.42 y-z | 64.71±7.56 p | 4.81±1 y-z | 16.45±0.51 a |
| Mousa Abadi | Control | 32.00±1.22 e | 100.00±0.0 a | 5.78±1 p-u | 30.00±1.87 j-l |
| | A | 30.44±1.74 e-f | 100.00±0.0 a | 5.61±1 s-w | 29.48±0.87 k-m |
| | B | 26.88±1.69 i-n | 93.80±3.13 b-e | 5.33±1 w-x | 26.65±0.75 n-r |
| | C | 22.11±2.02 s-v | 78.71±5.28 l-n | 5.12±1 x-y | 21.75±0.72 u-x |
| | D | 15.00±1.22 z | 52.47±4.98 q | 4.57±1 z | 14.90±1.07 b |
| Ebrahimi | Control | 29.33±1.93 f-h | 100.00±0.0 a | 6.07±0.09 p-r | 33.67±1.58 e-f |
| | A | 28.77±1.20 f-i | 100.00±0.0 a | 6.08±1.29 p-r | 33.55±1.26 e-f |
| | B | 27.44±1.33 g-k | 91.85±2.60 d-h | 5.75±0.66 p-u | 31.26±1.29 h-j |
| | C | 23.67±1.32 q-u | 84.68±4.53 i-k | 5.44±0.09 u-x | 26.56±1.44 n-q |
| | D | 19.33±1.32 u-w | 62.98±8.62 p | 5.17±0.09 w-y | 22.15±1.34 s-v |
| Badami Zarand | Control | 25.00±1.22 n-r | 100.00±0.0 a | 6.73±0.05 h-j | 29.32±1.09 k-m |
| | A | 24.67±1.32 o-s | 100.00±0.0 a | 6.69±0.06 h-j | 29.35±1.30 k-m |
| | B | 23.33±1.0 q-u | 97.39±0.0 a-c | 6.56±0.08 j-l | 27.40±0.92 m-q |
| | C | 21.44±1.23 t-v | 93.00±3.37 c-h | 6.25±0.06 m-p | 24.51±0.81 r-t |
| | D | 17.78±1.48 v-y | 83.71±4.45 j-l | 5.80±0.12 p-u | 21.19±0.90 w-x |
| Fandoghi 48 | Control | 35.00±1.87 d | 100.00±0.0 a | 6.62±0.19 i-j | 36.53±1.11 d |
| | A | 34.33±1.58 d | 100.00±0.0 a | 6.53±0.11 j-m | 36.23±0.92 d |
| | B | 31.11±1.69 e-f | 94.55±4.30 b-e | 6.30±0.10 k-o | 33.17±1.26 e-g |
| | C | 26.77±1.85 j-o | 87.96±2.29 h-j | 5.90±0.15 q-s | 29.34±1.65 k-m |
| | D | 21.11±1.69 t-w | 75.97±6.88 o | 5.67±0.09 s-w | 23.45±1.02 s-v |
| Sabs Pesteh Togh | Control | 32.00±1.50 e | 100.00±0.0 a | 6.43±0.09 j-n | 28.22±1.21 l-o |
| | A | 31.67±0.86 e | 100.00±0.0 a | 6.44±0.05 j-n | 27.73±1.10 m-p |
| | B | 28.00±1.87 g-k | 93.78±0.05 b-g | 6.13±0.08 n-p | 25.70±0.92 p-r |
| | C | 24.33±1.32 p-t | 83.08±3.09 h-j | 5.73±0.08 s-w | 22.91±0.29 s-v |
| | D | 20.11±1.45 t-w | 67.29±5.39 no | 5.33±0.09 u-x | 21.01±0.64 w-x |
| Ahmad Aghaee | Control | 30.00±1.87 e-g | 100.00±0.0 a | 5.71±0.11 s-w | 23.11±1.16 s-w |
| | A | 27.88±1.16 g-k | 100.00±0.0 a | 5.67±0.08 s-w | 21.33±1.32 w-x |
| | B | 25.00±1.22 n-s | 95.55±3.16 a-e | 5.35±0.11 u-x | 18.33±0.96 y-z |
| | C | 22.11±1.26 s-v | 82.32±4.41 kl | 5.11±0.08 x-y | 17.21±0.54 z |
| | D | 19.04±0.72 u-x | 72.01±2.50 o | 4.73±0.08 y-z | 16.22±0.66 $a^{/*}$ |
| Rezaie Zodres | Control | 30.67±1.32 e-g | 100.00±0.0 a | 5.81±0.18 p-u | 34.63±2.23 e |
| | A | 29.22±1.30 f-h | 100.00±0.0 a | 5.50±0.26 u-x | 32.22±1.27 e-h |
| | B | 25.77±1.71 m-r | 91.76±5.73 d-h | 5.17±0.16 w | 28.11±1.32 m-p |
| | C | 20.55±1.01 t-w | 75.51±6.87 no | 5.05±0.33 x-y | 23.46±1.48 s-v |
| | D | 16.00±0.86 y-z | 53.48±4.82 q | 4.49±0.24 z-a | 17.95±1.08 y-z |
| Shahpasand | Control | 45.00±1.65 a | 100.00±0.0 a | 7.77±0.11 c | 47.51±1.40 a |
| | A | 43.67±1.0 a | 100.00±0.0 a | 7.65±0.10 c | 47.07±1.29 a |
| | B | 41.67±0.70 a-b | 98.55±0.0 a-b | 7.52±0.10 cd | 45.01±0.98 a-b |
| | C | 39.11±1.16 c | 93.89±1.81 b-g | 7.21±0.06 e-f | 42.19±3.33 c |
| | D | 35.33±1.58 d | 83.01±4.73 j-l | 6.90±0.09 g-i | 37.01±1.06 d |

Means in each column and for each factor, followed by similar letter(s) are not significantly different at the 1% probability level, using Duncan's Multiple Range Test.

*= $a^{/}$ is less than z. Given that variety of data was very wide, Duncan's test grouped data between a to z and less than z such as $a^{/}$, $b^{/}$, $c^{/}$, $d^{/}$ and $e^{/}$.

plants of Shahpasand cultivar (45±1.65 leaves), and the lowest amount of them were observed in Mousa Abadi, Kaleh Ghochi, Jandaghi and Rezaie Zood Res cultivars in salinity level D (15±1.22, 15.33±1.00, 15.44±1.42 and 16±0.86 leaves), respectively.

The results showed that with increasing salinity of irrigation water, the percentage of green leaves in all cultivars was decreased. In control plants and also plants treated with salinity level A, all leaves of plants were green and were not observed any necrotic leaves. Necrosis and fallen leaves in all cultivars were observed in salinity levels B (except for Akbari cultivar), C and D. The lowest percentage of green leaves was found in salinity level D and in Mousa Abadi (52.47±4.98%), and Rezaie Zood Res (53.48±4.82%), cultivars, respectively.

As reported in Table 5, in all the cultivars as the salinity increases, the percentage of necrosis leaves were increased and the first symptoms of necrosis except for Akbari cultivar were observed in salinity level A. In all cultivars, the highest incidence of necrosis leaves was observed in salinity level D. The percentage of fallen leaves also were increased with increasing salinity levels while in all cultivars except for Akbari and Ghazvini cultivars were observed fallen leaves in salinity levels C and D.

The results showed that leaves and shoots fresh and dry weights in all studied cultivars significantly decreased by applying salinity stress and increasing its concentration. Shoots and leaves fresh and dry weights in Kaleh Ghochi, Italiyayi, Jandaghi, Fndoghi 48, Ebrahimi, Mousa Abadi and Rezaei Zood Res cultivars in salinity levels B, C and D, and in Khanjari, Sabz Pesteh Tohg, Ahmad Aghaee and Badami Zarand cultivars in salinity levels C and D, and in Akbari, Shahpasand and Qazvini cultivars only in salinity level D, were decreased significantly compared to control plants.

Based on the results of this study, as the salinity increases, the amount of minimum chlorophyll fluorescence ($F_0$) was increased significantly. The highest amount of $F_0$ in all cultivars was observed in salinity level D. The highest amount of $F_0$ was observed in the leaves of Khanjari cultivar treated with salinity level D (Table 7). Also, maximum chlorophyll fluorescence ($F_m$) in all cultivars was decreased significantly as the salinity increased. The highest amount of $F_m$ was observed in control plants while the lowest amount of $F_m$ was observed in Rezaie Zood Res (365.22±20.90), Jandaghi (380.67±11.69) and Mousa Abadi (387.67±29.06) cultivars that was treated with salinity level D, respectively (Table 7).

The results showed that in all studied cultivars, ($F_v/F_m$) ratio was reduced significantly by applying salinity stress and increasing its concentration. Furthermore, there was a significant difference $F_v/F_m$ values in different levels of salinity among tested cultivars. In the leaves of the control plants $F_v/F_m$ was 0.83±1 indicating the existence of ideal and non-stressed environmental conditions for the growth of all cultivars throughout the experimental period.

Regarding changes in ($F_v/F_m$) ratio the stress intensity in Rezaie Zood Res and Mousa Abadi cultivars was more severe than other cultivars, (0.59±0.015 and 0.61±0.009 respectively). Therefore, the susceptibility of these cultivars to salinity stress in levels C and D were higher than other cultivars. On the contrary, Gazvini and Akbari cultivars were less damaged, (0.76±0.003 and 0.75±0.007, respectively) (Table 7). In other words, $F_v/F_m$ in this cultivars, showed the lowest decrease.

Results on chlorophyll a, b and total chlorophyll content of the leaves treated in different salinity levels are reported in Table 8. Chlorophyll a content was reduced significantly in all of the studied cultivars in salinity level D compared to control plants while chlorophyll b content in salinity levels C and D was reduced significantly compared to the control plants. Total chlorophyll content was decreased significantly in Ghazvini cultivar only in salinity level D, and in Akbari and Badami Zarani cultivars in salinity levels C and D while total chlorophyll content in other cultivars decreased significantly in salinity levels B, C and D (Table 8). Chlorophyll index was decreased significantly under salinity stress. The lowest chlorophyll index was observed in the leaves of the plants that were irrigated with salinity level D. The highest reduction in chlorophyll index was observed in Mousa abadi (22.60±1.50), Jandaghi (27.83±0.98) and Kaleh Ghochi (31.47±3.08) cultivars. The lowest reduction in chlorophyll index was observed in Shahpasand (55.35±1.35), Akbari (53.70±1.24) and Ghazvini (49.78±1.10) cultivars (Table 8).

According to the results reported in Table 9, the content of relative humidity of leaves decreased significantly as the salinity increased. The content of relative humidity in leaves of control plants were higher than 79.83% (of 79.83±0.24% in control plant leaves of Shahpasand cultivar to 85.25±0.64% in control plant leaves of Khanjari cultivar), while relative humidity content in leaves of Mousa Abadi, Rezaie Zood Res and Sabz Pesteh Togh plants in salinity level D, were 64.17±0.52%, 66.49±0.57% and 66.95±0.77%, respectively. In Ghazvini and Akbari cultivars

Table 5 - Effect of interaction between salinity and cultivar on the morphologic traits measured

| Cultivar | Treatments | Leaf dry weight (g) | Leaf fresh weight (g) | Downfall leaves (%) | Necrosis leaves (%) |
|---|---|---|---|---|---|
| Khanjari | Control | 2.77±0.02 d-f | 6.28±0.06 e-f | 0.00±0.0 l | 0.00±0.0 q |
| | A | 2.77±0.01 d-f | 6.30±0.02 e-f | 0.00±0.0 l | 0.00±0.0 q |
| | B | 2.67±0.02 f-g | 6.05±0.06 f-g | 0.00±0.0 l | 2.98±3.81 n-q |
| | C | 2.54±0.01 g-i | 5.71±0.03 h | 11.72±3.47 d | 16.07±4.47 d-e |
| | D | 2.47±0.03 h-k | 5.04±0.06 k-m | 19.24±3.22 b | 29.35±4.24 a |
| Akbari | Control | 1.73±0.12 s-u | 3.67±0.26 q-t | 0.00±0.0 l | 0.00±0.0 q |
| | A | 1.61±0.05 t-u | 3.41±0.11 r-u | 0.00±0.0 l | 0.00±0.0 q |
| | B | 1.48±0.04 u-x | 3.16±0.10 s-v | 0.00±0.0 l | 0.00±0.0 q |
| | C | 1.43±0.06 v-x | 2.95±0.14 t-w | 0.00±0.0 l | 3.14±4.23 m-q |
| | D | 1.34±0.06 w-y | 2.69±0.13 u-x | 0.00±0.0 l | 10.57±4.34 f-h |
| Ghazvini | Control | 2.45±0.06 h-l | 5.44±0.15 h-j | 0.00±0.0 l | 0.00±0.0 q |
| | A | 2.44±0.02 h-l | 5.41±0.05 h-j | 0.00±0.0 l | 0.00±0.0 q |
| | B | 2.40±0.06 h-l | 5.30±0.13 i-k | 0.00±0.0 l | 0.45± 0.30 q |
| | C | 2.31±0.06 k-o | 5.02±0.13 j-l | 0.00±0.0 l | 3.28±5.63 m-q |
| | D | 2.25±0.21 m-p | 4.76±0.44 l-n | 0.00±0.0 l | 9.12±3.68 g-i |
| Italiaie | Control | 2.52±0.18 h-j | 5.70±0.42 h | 0.00±0.0 l | 0.00±0.0 q |
| | A | 2.54±0.15 h-j | 5.75±0.35 g-h | 0.00±0.0 l | 0.00±0.0 q |
| | B | 2.30±0.10 k-o | 5.14±0.24 j-l | 0.00±0.0 l | 1.15±2.40 p-q |
| | C | 1.98±0.13 o-s | 4.38± 0.29 o-p | 3.78±3.50 g-l | 5.50±5.62 i-n |
| | D | 1.73±0.18 s-u | 3.77±0.39 q-t | 5.13± 3.05 f-j | 8.99±3.09 g-j |
| Kaleh Ghoch | Control | 2.36±0.16 h-m | 5.13±0.36 i-k | 0.00±0.0 l | 0.00±0.0 q |
| | A | 2.37±0.07 h-m | 5.13±0.16 i-k | 0.00±0.0 l | 0.00±0.0 q |
| | B | 2.01±0.06 o-s | 4.29±0.13 o-p | 1.19±2.50 kl | 1.15±3.04 p-q |
| | C | 1.58±0.08 t-u | 3.32±0.17 r-u | 4.91±2.70 f-k | 5.49±2.78 i-n |
| | D | 1.18±0.11 y-z | 2.43±0.15 v-y | 17.10±7.08 b-c | 9.98±6.03 f-h |
| Jandaghi | Control | 2.92±0.23 c-d | 6.41±0.24 e | 0.00±0.0 l | 0.00±0.0 q |
| | A | 2.89±0.06 c-e | 6.32±0.50 e-f | 0.00±0.0 l | 0.00±0.0 q |
| | B | 2.55±0.18 g-h | 5.53±0.14 hi | 1.87± 1.90 i-l | 2.33±2.95 n-q |
| | C | 1.95±0.12 p-t | 4.13±0.38 p-r | 11.54± 4.80 d | 7.50±4.54 g-l |
| | D | 1.41±0.04 v-x | 2.90±0.26 t-w | 17.74± 6.60 b-c | 17.55±6.71 cd |
| Mousa Abadi | Control | 1.83±0.02 r-t | 4.07±0.09 p-r | 0.00±0.0 l | 00.00±0.0 q |
| | A | 1.91±0.09 p-t | 3.99±0.06 p-s | 0.00±0.0 l | 00.00±0.0 q |
| | B | 1.51±0.10 u-x | 3.22±0.20 s-u | 2.65±1.30 i-l | 3.55±1.50 m-q |
| | C | 1.18±0.05 y-z | 2.43±0.22 v-y | 8.15± 2.50 d-f | 13.04±2.74 e-f |
| | D | 0.72±0.12 z | 1.42±0.11 z | 27.06± 4.90 a | 20.47±4.70b-c |
| Ebrahimi | Control | 1.94±0.07 p-s | 4.52 ±0.29m-o | 0.00±0.0 l | 00.00±0.0 q |
| | A | 1.87±0.10 r-t | 4.32±0.18 o-p | 0.00±0.0 l | 00.00±0.0 q |
| | B | 1.61±0.04 t-u | 3.61±0.23 q-t | 3.82±2.33 g-l | 5.33±2.11 j-o |
| | C | 1.22±0.12 x-y | 2.70±0.09 u-x | 5.02±2.89 f-k | 9.29±3.24 f-h |
| | D | 0.71±0.12 z | 1.50±0.25 y-z | 15.05±2.95 c | 21.96±3.11 b |
| Badami Zarand | Control | 2.47±0.13 h-k | 5.25±0.25 i-k | 0.00±0.0 l | 0.00±0.0 q |
| | A | 2.43±0.09 h-k | 5.15±0.27 j-k | 0.00±0.0 l | 0.00±0.0 q |
| | B | 2.29±0.11 k-o | 4.91±0.20 k-m | 0.00±0.0 l | 2.61±1.11 n-q |
| | C | 2.08±0.14 o-r | 4.28±0.24 o-p | 3.50±2.70 h-l | 3.50±2.51 m-q |
| | D | 1.71±0.16 s-u | 3.41±0.28 r-u | 5.64±2.99 f-i | 10.65±3.80 f-h |
| Fandoghi 48 | Control | 3.11±0.14 c | 7.03±0.37 d | 0.00±0.0 l | 0.00±0.0 q |
| | A | 3.06±0.14 c | 6.87±0.31 d | 0.00±0.0 l | 0.00±0.0 q |
| | B | 2.73±13 e-f | 6.07±0.32 f-g | 0.00±0.0 l | 5.45±2.37 l-p |
| | C | 2.29±0.15 k-m | 4.98±0.34 k-m | 3.74±2.50 g-l | 8.28±2.30 g-k |
| | D | 1.73±0.13 s-u | 3.67±0.29 q-t | 18.15±3.70 b-c | 15.88±3.53 de |
| Sabs Pesteh Togh | Control | 2.34±0.04 j-n | 4.99±0.09 k-m | 0.00±0.0 l | 0.00±0.0 a |
| | A | 2.35±0.05 j-n | 4.99±0.12 k-m | 0.00±0.0 l | 0.00±0.0 a |
| | B | 2.29±0.06 k-o | 4.76±0.13 m-n | 1.11±1.17 j-l | 5.01±1.39 k-p |
| | C | 2.13±0.08 o-r | 4.33±0.16 o-p | 6.88±2.70 e-h | 10.04±2.84 f-h |
| | D | 1.98±0.08 o-s | 3.96±0.17 p-s | 14.46±3.67 cd | 18.25±3.53 cd |
| Ahmad Aghaee | Control | 1.89±0.05 p-u | 3.85±0.11 p-s | 0.00±0.0 l | 0.00±0.0 q |
| | A | 1.87±0.03 p-t | 3.68±0.06 q-t | 0.00±0.0 l | 0.00±0.0 q |
| | B | 1.78±0.04 s-t | 3.48±0.08 r-u | 0.50±1.10 l | 3.95±2.73 l-q |
| | C | 1.66±0.04 t-v | 3.18±0.08 t-v | 6.56±2.12 e-h | 11.12±2.64 f-g |
| | D | 1.42±0.05 v-x | 2.66±0.09 u-x | 11.37±2.50 d | 16.62±2.56 de |
| Rezaie Zodres | Control | 2.27±0.05 k-m | 4.52±0.10 m-o | 0.00±0.0 l | 0.00±0.0 q |
| | A | 2.25±0.03 k-m | 4.45±0.05 m-o | 0.00±0.0 l | 0.00±0.0 q |
| | B | 2.15±0.04 m-p | 4.21±0.07 p-s | 1.31±0.70 j-l | 6.93±3.84 h-m |
| | C | 1.85±0.067 r-t | 3.56±0.13 q-t | 9.31±3.12 de | 15.18±3.82 de |
| | D | 1.58±0.05 t-u | 2.97±0.09 t-w | 27.41±4.45 a | 29.11±4.80 a |
| Shahpasand | Control | 4.34±0.05 a | 8.36±0.10 a | 0.00±0.0 l | 0.00±0.0 q |
| | A | 4.34±0.02 a | 8.32±0.05 a | 0.00±0.0 l | 0.00±0.0 q |
| | B | 4.29± 0.03 a | 8.17±0.06 a-b | 0.00±0.0 l | 1.45±0.5 o-q |
| | C | 4.23±0.05 a | 7.93±0.10 b | 3.06±1.50 h-l | 3.05±1.62 m-q |
| | D | 4.02±0.08 b | 7.41±0.16 c | 7.54±3.01 e-g | 9.45±3.08 f-h |

Means in each column and for each factor, followed by similar letter(s) are not significantly different at the 1% probability level, using Duncan's Multiple Range Test.

Table 6 - Effect of interaction between salinity and cultivar on the morphologic traits measured

| Cultivar | Treatments | Branch fresh weight (g) | Root fresh weight (g) | Root dry weight ratio to aerial organ dry weight | Root fresh weight ratio to aerial organ fresh weight |
|---|---|---|---|---|---|
| Khanjari | Control | 4.42±0.02 g-i | 8.12±0.13 i-l | 0.65±0.01 m-v | 0.76±0.01 o-y |
| | A | 4.38±0.01 g-j | 8.13±0.07 h-l | 0.65±0.01 m-v | 0.76±0.01 o-y |
| | B | 4.16±0.05 h-m | 7.75±0.28 l-o | 0.67±0.02 m-u | 0.78±0.02 o-x |
| | C | 3.69±0.05 j-s | 6.69±0.11 r-s | 0.69±0.01 m-u | 0.81±0.01 m-u |
| | D | 3.01±0.06 r-z | 6.14± 0.06 t-u | 0.73±0.01 k-s | 0.88±0.01 i-r |
| Akbari | Control | 3.25±0.36 o-x | 8.58±0.51 f-i | 0.99±0.08 c-j | 1.24±0.10 c-f |
| | A | 3.17±0.34 o-x | 8.51±0.25 f-j | 1.03±0.05 c-h | 1.28±0.06 c-e |
| | B | 2.99±0.16 s-z | 8.01±0.14 j-n | 1.03±0.04 c-h | 1.28±0.05 c-e |
| | C | 2.76±0.15 u-a′ | 7.95±0.05 j-n | 1.04±0.04 c-g | 1.31±0.06 c-e |
| | D | 2.28±0.20 a′-c′ | 7.79±0.04 l-o | 1.11±0.06 c-d | 1.42±0.08 a-c |
| Ghazvini | Control | 3.44±0.16 n-v | 9.46±0.15 a-b | 0.91±0.02 d-l | 1.06 ±0.02e-n |
| | A | 3.38±0.08 o-w | 9.42±0.35 a-b | 0.91±0.03 d-l | 1.07±0.04 e-n |
| | B | 3.18±0.07 o-x | 9.35±0.03 a-b | 0.94±0.01 d-k | 1.10±0.01 e-k |
| | C | 2.66±0.14 v-a′ | 9.29±0.03 a-c | 1.03±0.01 c-h | 1.21±0.03 c-g |
| | D | 2.42±0.16 y-b′ | 9.15±0.04 a-e | 1.09±0.07 c-e | 1.28±0.08 c-e |
| Italiaie | Control | 4.35±0.39 g-k | 9.60±0.07 a | 0.82±0.06 g-n | 0.96±0.06 g-p |
| | A | 4.23±0.15 h-l | 9.58±0.05 a | 0.83±0.03 g-n | 0.96±0.03 g-p |
| | B | 3.89±0.12 h-o | 9.41±2.98 a-b | 0.85±0.28 f-n | 0.99 f±0.33-o |
| | C | 3.30±0.14 o-x | 9.19±0.06 a-d | 1.02±0.05 c-i | 1.19±0.06 c-h |
| | D | 2.72±0.22 v-a′ | 8.96±0.07 b-f | 1.20±0.09 b-c | 1.37±0.10 b-d |
| Kaleh Ghochi | Control | 3.21±0.08 o-x | 5.46±0.07 w-y | 0.56±0.01 p-w | 0.65±0.01 r-y |
| | A | 3.12±0.08 p-y | 5.46±0.03 w-y | 0.57±0.01 o-w | 0.67±0.01 q-y |
| | B | 2.74±0.08 v-a′ | 5.41±0.04 w-z | 0.66±0.01 m-u | 0.77±0.02 o-y |
| | C | 2.23±0.06 a′-c′ | 5.20±0.05 w-a′ | 0.80±0.03 h-p | 0.93±0.04 h-q |
| | D | 1.62±0.03 c′ | 4.90±0.03 z-b′ | 1.03±0.04 c-h | 1.21±0.05 c-g |
| Jandaghi | Control | 3.49±0.10 m-u | 5.24±0.06 w-a′ | 0.46±0.01 u-w | 0.53±0.01 v-y |
| | A | 3.42±0.15 n-v | 5.22±0.04 w-a′ | 0.47±0.02 t-w | 0.54±0.02 u-y |
| | B | 2.90±0.07 t-z | 5.01±0.07 y-b′ | 0.52±0.01 r-w | 0.59±0.01 t-y |
| | C | 2.34± 0.08 z-b′ | 4.78±0.05 a′-c′ | 0.65±0.03 m-v | 0.74±0.04 o-y |
| | D | 1.81±0.05 b′ | 4.28±0.03 d′ | 0.79±0.03 i-p | 0.91±0.04 i-r |
| Mousa Abadi | Control | 3.30±0.20 o-w | 5.16±0.18 w-a′ | 0.63±0.03 n-w | 0.70±0.03 p-y |
| | A | 3.18±0.09 o-w | 5.08±0.10 y-a′ | 0.63±0.01 n-w | 0.71±0.01 p-y |
| | B | 2.46±0.07 x- a′ | 4.97±0.07 y-b′ | 0.75±0.02 k-r | 0.84±0.03 k-t |
| | C | 1.96±0.06 a′- d′ | 4.53±0.05 b′-d′ | 0.95±0.03 d-k | 1.08±0.04 e-l |
| | D | 1.16±0.08 d′ | 4.13±0.07 d′e′ | 1.39±0.06 a-b | 1.60±0.07 a-b |
| Ebrahimi | Control | 5.05±0.23 e-g | 7.51±0.09 n-p | 0.76±0.03 j-q | 0.79±0.03 n-w |
| | A | 5.04±0.18 e-g | 7.49±0.06 n-q | 0.77±0.02 j-p | 0.80±0.02 n-v |
| | B | 4.41±0.18 f-j | 7.32±0.04 o-q | 0.87±0.02 e-m | 0.91±0.02 i-r |
| | C | 3.50±0.19 m-t | 7.04±0.07 p-r | 1.07±0.03 c-f | 1.13±0.03 d-j |
| | D | 2.68±0.16 w-a′ | 6.69±0.06 r-s | 1.47±0.13 a | 1.61±0.16 a |
| Badami Zarand | Control | 5.57±0.20 d-e | 8.80±0.09 c-g | 0.78±0.02 j-p | 0.81±0.02 m-u |
| | A | 5.54±0.24 d-e | 8.73±0.13 d-g | 0.78±0.03 j-p | 0.82±0.03 l-t |
| | B | 5.10±0.17 e-f | 8.65±0.13 e-h | 0.84±0.02 g-n | 0.87±0.03 j-s |
| | C | 4.41±0.14 g-j | 8.32±0.26 g-k | 0.92±0.03 d-l | 0.96±0.04 g-p |
| | D | 3.64±0.15 k-s | 8.06±0.17 i-m | 1.09±0.05 c-e | 1.14±0.06 d-i |
| Fandoghi 48 | Control | 7.71±0.23 a-b | 7.62±0.11 l-o | 0.41±0.01 w | 0.51±0.01 x-y |
| | A | 7.60±0.19 a-b | 7.58±0.05 m-o | 0.42±0.01 v-w | 0.52±0.01 w-y |
| | B | 6.81±0.25 c | 7.30±0.09 o-q | 0.46±0.01 u-w | 0.57±0.01 t-v |
| | C | 5.78±0.32 d | 6.99±0.08 q-s | 0.52±0.02 r-w | 0.65±0.033 r-y |
| | D | 4.36±0.19 g-j | 6.50±0.14 s-t | 0.65±0.03 m-v | 0.82±0.04 l-t |
| Sabs Pesteh Togh | Control | 3.81±0.16 i-p | 6.02±0.11 t-v | 0.69±0.02 l-u | 0.68±0.02 q-y |
| | A | 3.74±0.14 i-r | 5.99±0.07 u-v | 0.70±0.01 l-t | 0.69±0.01 p-y |
| | B | 3.21±0.11 o-x | 5.71±0.18 u-w | 0.73±0.01 k-s | 0.71±0.01 p-y |
| | C | 2.61±0.03 x-a′ | 5.38±0.14 w-z | 0.78±0.01 j-p | 0.78±0.01 o-x |
| | D | 2.14±0.06 a′-c′ | 4.95±0.11 y-a′ | 0.82±0.02 g-n | 0.81±0.02 m-u |
| Ahmad Aghaee | Control | 3.83±0.07 i-p | 5.72±0.06 u-w | 0.76±0.01 j-q | 0.75±0.01 o-y |
| | A | 3.76±0.03 i-q | 5.73 ±0.07u-w | 0.79±0.01 j-p | 0.77±0.01 o-y |
| | B | 3.55±0.07 l-t | 5.61±0.07 v-x | 0.82±0.01 g-n | 0.80±0.01 m-v |
| | C | 3.35±0.07 o-w | 5.47±0.08 w-y | 0.86±0.01 f-n | 0.84±0.01 k-t |
| | D | 2.85±0.09 t-z | 5.02±0.07 y-a′ | 0.91±0.01 d-l | 0.91±0.01 i-r |
| Rezaie Zodres | Control | 4.56±0.09 f-h | 4.56±0.12 b′-d′ | 0.49±0.01 t-w | 0.50±0.01 y |
| | A | 4.46±0.12 f-i | 4.41±0.11 b′-d′ | 0.50±0.02 s-w | 0.50±0.02 y |
| | B | 4.13±0.09 i-n | 4.28±0.16 d′ | 0.51±0.01 s-w | 0.51±0.01 x-y |
| | C | 3.78±0.09 i-q | 3.98±0.15 e′ | 0.53±0.02 q-w | 0.54±0.02 u-y |
| | D | 3.05±0.10 q-z | 3.53±0.09 f′ | 0.58±0.01 o-w | 0.59±0.01 t-y |
| Shahpasand | Control | 8.01±0.07 a | 9.44±0.11 a-b | 0.47±0.01 t-w | 0.57±0.01 t-y |
| | A | 7.98±0.08 a | 9.43±0.08 a-b | 0.48±0.01 t-w | 0.58±0.01 t-y |
| | B | 7.83±0.12 a-b | 9.21±0.05 a-d | 0.48±0.01 t-w | 0.58±0.01 t-y |
| | C | 7.49±0.07 a-b | 8.98±0.13 b-f | 0.49±0.01 t-w | 0.59±0.01 t-y |
| | D | 7.18±0.10 b-c | 8.53±0.16 f-i | 0.50±0.01 s-w | 0.60±0.01 s-y |

Means in each column and for each factor, followed by similar letter(s) are not significantly different at the 1% probability level, using Duncan's Multiple Range Test.

*= a′ is less than z. Given that variety of data was very wide, Duncan's test grouped data between a to z and less than z such as a′, b′, c′, d′ and e′.

Table 7 - Effect of interaction between salinity and cultivar on chlorophyll fluorescence parameters

| Cultivar | Treatments | ($F_v/F_m$) | Maximum florescence ($F_m$) | Minimum florescence ($F_o$) |
|---|---|---|---|---|
| Khanjari | Control | 0.82±0.003 b-c | 603.67±3.46 b-d | 107.22±1.71 r-u |
| | A | 0.82±0.003 b-c | 606.44±3.39 b-d | 110.67±1.58 o-r |
| | B | 0.80±0.005 d-e | 586.00±8.74 e-f | 116.55±1.66 k-m |
| | C | 0.74±0.015 j-k | 540.33±5.50 k-m | 139.88±8.52 e |
| | D | 0.65±0.025 q | 467.77±5.65 r | 163.11±11.20 a |
| Akbari | Control | 0.83±0.002 a-b | 625.44±6.72 a | 106.11±2.31 s-u |
| | A | 0.82±0.004 b-c | 617.67±5.85 a-c | 109.77±2.16 p-s |
| | B | 0.82±0.007 b-c | 614.11±5.01 a-c | 110.55±3.77 o-s |
| | C | 0.78±0.003 f-g | 607.11±7.09 b-d | 134.22±2.38 f-g |
| | D | 0.75±0.007 i-j | 555.44±11.58 h-k | 141.33±1.58 e |
| Ghazvini | Control | 0.82±0.003 b-c | 602.44±11.54 c-d | 106.11±3.51 s-u |
| | A | 0.82±0.003 b-c | 602.55±17.00 c-d | 108.67±4.09 q-t |
| | B | 0.81±0.004 c-d | 591.00±2.87 d-f | 109.77±2.27 o-s |
| | C | 0.80±0.003 c-e | 578.33±5.61 d-g | 118.67±1.93 j-m |
| | D | 0.76±0.003 h-i | 538.11±4.59 l-m | 129.33±2.39 h |
| Italiaie | Control | 0.83±0.004 a-b | 600.77±7.41 c-e | 101.22±3.89 v-w |
| | A | 0.83±0.003 a-b | 604.22±9.31 b-d | 103.77±3.70 t-v |
| | B | 0.81±0.004 c-d | 576.44±3.71 f-g | 112.00±2.39 n-q |
| | C | 0.78±0.008 f-g | 532.11±13.50 m | 117.11±2.14 k-m |
| | D | 0.73±0.009 l | 488.67±6.61 o-q | 133.55±5.12 f-g |
| Kaleh Ghochi | Control | 0.83±0.002 a-b | 538.44±9.46 l-m | 93.22±1.98 y-z |
| | A | 0.82±0.005 b-c | 542.88±5.94 j-m | 93.33±2.64 y-z |
| | B | 0.80±0.005 d-e | 529.88±7.18 m | 106.44±2.29 s-u |
| | C | 0.76±0.005 h-i | 489.00±8.38 o-q | 119.55±3.20 i-k |
| | D | 0.69±0.009 m | 444.11±12.31 s | 137.00±3.46 e-f |
| Jandaghi | Control | 0.83±0.005 a-b | 580.33±18.67 f | 100.67±2.64 v-w |
| | A | 0.82±0.006 b-c | 557.00±3.80 h-j | 101.44±3.46 v-w |
| | B | 0.77±0.006 g-h | 479.88±6.73 p-r | 110.33±2.54 p-s |
| | C | 0.7±0.0043 l | 417.33±9.04 t-u | 113.89±3.25 m-p |
| | D | 0.66±0.004 p | 380.67±11.69 w | 129.44±3.08 h |
| Mousa Abadi | Control | 0.84 a±0.005 | 551.78±7.15 h-l | 91.00±2.87 z |
| | A | 0.82±0.007 b-c | 530.00±7.29 m | 94.00±3.57 x-z |
| | B | 0.79±0.002 e-f | 495.22±14.77 op | 104.55±3.46 t-v |
| | C | 0.73±0.008 kl | 447.22±21.89 s | 122.44±4.97 i-j |
| | D | 0.61±0.009 s | 387.67±29.06 w | 151.00±10.34 b-c |
| Ebrahimi | Control | 0.83±0.003 a-b | 608.11±8.08 b-c | 104.55±2.50 t-v |
| | A | 0.83±0.004 a-b | 609.67±8.17 a-c | 105.44±3.77 t-v |
| | B | 0.80±0.006 d-e | 586.44±10.27 e-f | 114.44±3.35 m-p |
| | C | 0.77±0.006 g-h | 539.67±14.41 k-m | 123.67±4.24 i |
| | D | 0.73±0.011 kl | 512.44±12.28 n | 140.67±4.44 e |
| Badami Zarand | Control | 0.82±0.003 b-c | 602.44±9.83 cd | 105.55±2.12 s-u |
| | A | 0.82±0.002 b-c | 606.33±8.81 a-c | 106.55±2.45 s-u |
| | B | 0.81±0.003 c-d | 597.11±10.32 d-f | 108.55±1.58 q-t |
| | C | 0.77± 0.007 g-h | 542.55±13.92 j-m | 124.44±4.92 i |
| | D | 0.73±0.004 k-l | 512.67±12.79 n | 137.44±3.16 e-f |
| Fandoghi 48 | Control | 0.84±0.006 a | 585.44±10.90 f | 95.11±2.97 x-z |
| | A | 0.83±0.004 a-b | 585.48±9.48 f | 98.11±2.47 w-x |
| | B | 0.79±0.004 e-f | 579.00±8.95 f | 118.89±3.33 j-m |
| | C | 0.73±0.010 k-l | 491.44±10.87 o-q | 131.55±4.63 g-h |
| | D | 0.64±0.018 r | 404.55±14.39 u-v | 147.33±4.74 d |
| Sabs Pesteh Togh | Control | 0.83±0.005 a-b | 562.00±14.96 g-h | 95.67±1.73 x-y |
| | A | 0.82±0.007 b-c | 539.00±21.68 l-m | 97.77±1.78 w-x |
| | B | 0.76±0.009 h-i | 470.89±14.88 r | 110.88±2.52 o-r |
| | C | 0.72±0.007 l | 427.11±15.39 t | 118.55±4.15 j-l |
| | D | 0.67±0.009 o | 409.11±14.58 u | 134.00±3.93 f-g |
| Ahmad Aghaee | Control | 0.83±0.003 a-b | 610.33±12.40 a-c | 106.44±2.24 s-u |
| | A | 0.82±0.004 b-c | 603.22±19.07 cd | 111.22±3.07 o-r |
| | B | 0.78±0.011 f-g | 543.89±20.01 i-m | 117.11±2.61 k-m |
| | C | 0.75±0.009 i-j | 510.33±12.10 n | 130.00±3.27 g-h |
| | D | 0.67±0.022 o | 469.89±30.25 r | 153.33±4.66 b |
| Rezaie Zodres | Control | 0.84±0.008 a | 562.89±13.27 g-h | 92.67±3.04 y-z |
| | A | 0.82±0.006 b-c | 538.55±14.52 k-m | 95.67±2.00 x-y |
| | B | 0.76±0.012 h-i | 467.77±16.20 r | 105.33±3.60 t-v |
| | C | 0.68±0.016 n | 391.00±10.14 v-u | 123.55±5.41 i |
| | D | 0.59±0.015 t | 365.22±20.90 x | 147.77±7.52 cd |
| Shahpasand | Control | 0.83±0.003 a-b | 531.00±9.73 m | 86.67±2.00 a/ |
| | A | 0.83±0.004 a-b | 530.88±8.26 m | 88.00±1.58 a/ |
| | B | 0.82±0.007 b-c | 527.44±17.25 m-n | 95.11±2.52 x-z |
| | C | 0.79±0.012 e-f | 499.67±18.36 o-p | 105.77±2.81 s-u |
| | D | 0.75±0.011 i-j | 461.00±13.79 r | 115.00±3.42 l-o |

Means in each column and for each factor, followed by similar letter(s) are not significantly different at the 1% probability level, using Duncan's Multiple Range Test.

Table 8 - Effect of interaction between salinity and cultivar on the physiologic traits measured

| Cultivar | Treatments | Total chlorophyl (mg/g) | Chlorophyll b (mg/g) | Chlorophyll a (mg/g) | Chlorophyll index (SPAD) |
|---|---|---|---|---|---|
| Khanjari | Control | 1.13±0.03 k-n | 0.36±0.02 g-j | 0.77±0.02 g | 57.58±1.52 f-h |
| | A | 1.11±0.02 m-n | 0.36±0.04 g-j | 0.75±0.02 g-i | 56.62±1.62 g-j |
| | B | 1.06±0.02 p-r | 0.34±0.02 i-l | 0.72±0.05 i-k | 53.60±0.82 i-l |
| | C | 0.88±0.01 w | 0.31±0.01 l-o | 0.57±0.02 s | 48.55±1.50 o-q |
| | D | 0.59±0.02 a/ | 0.22±0.01 t | 0.37±0.04 w-x | 40.00±1.73 y-z |
| Akbari | Control | 1.45±0.007 c | 0.51±0.008 a | 0.95±0.003 c | 61.27±0.98 c-d |
| | A | 1.45±0.11 c | 0.52±0.008 a | 0.94±0.009 c | 61.40±1.57 c-d |
| | B | 1.40±0.02 c-d | 0.51±0.1 a | 0.89±0.03 c-d | 60.15±1.55 c-e |
| | C | 1.23±0.01 f | 0.46±0.03 cd | 0.77±0.01 g | 56.97±1.04 g-i |
| | D | 1.05±0.009 q-s | 0.38±0.02 e-h | 0.67±0.02 m-o | 53.70±1.24 k-m |
| Ghazvini | Control | 1.20±0.01 f-g | 0.46±0.007 c-d | 0.74±0.01 h-j | 55.17±1.27 g-l |
| | A | 1.21±.005 f-g | 0.47±0.01 c-d | 0.74±0.008 h-j | 54.67±1.25 i-l |
| | B | 1.17±0.006 g | 0.45±0.007 c-d | 0.72±0.005 j-k | 54.04±1.09 j-m |
| | C | 1.14±0.02 g-m | 0.43±0.008 d | 0.71±0.003 j-l | 51.98±0.85 l-n |
| | D | 0.97±0.004 t | 0.35± 0.01 h-k | 0.62±0.008 q-r | 49.78±0.82 n-o |
| Italiaie | Control | 1.10±0.01 m-o | 0.36±0.004 g-j | 0.74±0.003 h-j | 49.95±1.10 n-o |
| | A | 1.09±0.01 n-p | 0.36±0.004 g-j | 0.73±0.01 i-j | 50.02±1.38 n-o |
| | B | 1.04±0.007 q-s | 0.32±0.01 k-n | 0.72±0.003 j-k | 45.17±1.36 r-u |
| | C | 0.91±0.008 v | 0.26±0.009 q-r | 0.6±0.0075 op | 43.95±1.43 t-w |
| | D | 0.70±0.01 z | 0.20±0.004 t | 0.50±0.005 u | 40.41±1.46 x-z |
| Kaleh Ghochi | Control | 1.07±0.007 o-q | 0.38±0.008 e-h | 0.69±0.005 l-m | 45.17±0.60 r-u |
| | A | 1.06±0.008 p-r | 0.37±0.004 f-i | 0.69±0.003 l-m | 43.95±0.16 t-w |
| | B | 1.03±0.01 q-s | 0.37±0.004 f-i | 0.66±0.009 m-o | 41.50±0.28 u-z |
| | C | 0.80±0.009 x | 0.31±0.008 l-o | 0.49±0.02 u-v | 36.24±0.40 a/ |
| | D | 0.60±0.003 a/ | 0.22±0.01 t | 0.38±0.01 w-x | 31.47±3.08 b/ |
| Jandaghi | Control | 1.04±0.007 q-s | 0.36±0.04 g-j | 0.69±0.002 l-m | 42.77±0.82 u-x |
| | A | 1.04±0.008 q-s | 0.36±0.04 g-j | 0.68±0.004 l-n | 42.77±0.76 u-x |
| | B | 0.95±0.01 t-u | 0.32±0.03 k-n | 0.63±0.006 p-q | 38.54±1.37 y-z |
| | C | 0.74±0.004 y | 0.26±0.03 q-r | 0.48±0.010 u-v | 35.45±0.85 a/ |
| | D | 0.53±0.004 b/ | 0.17±0.004 u | 0.36±0.01 x | 27.83±0.98 c/ |
| Mousa Abadi | Control | 1.05±0.007 q-s | 0.36±0.008 g-j | 0.69±0.002 l-m | 42.40±0.95 v-y |
| | A | 1.04±0.008 q-s | 0.36±0.004 g-j | 0.68±0.003 l-n | 42.65±0.51 u-y |
| | B | 0.95±0.01 t-u | 0.30±0.005 m-p | 0.63±0.005 p-q | 38.11±1.00 z-a/ |
| | C | 0.72 ±0.01y-z | 0.23±0.01 s-t | 0.49±0.009 u-v | 32.33±1.10 b/ |
| | D | 0.48±0.03 c/ | 0.15±0.004 u | 0.33±0.008 y | 22.60±1.50 d/ |
| Ebrahimi | Control | 1.20±0.04 f-h | 0.45±0.03 d | 0.74±0.01 h-j | 55.21±1.22 g-l |
| | A | 1.19±0.008 g-i | 0.45±0.02 cd | 0.74±0.01 h-j | 54.97±1.65 h-l |
| | B | 1.12±0.02 l-n | 0.42±0.01 e-g | 0.70±0.008 j-l | 49.97±1.98 no |
| | C | 0.95±0.01 t-u | 0.35±0.01 h-k | 0.60±0.01 r | 45.51±1.88 r-t |
| | D | 0.74±0.01 y | 0.27±0.01 p-r | 0.47±0.01 v | 40.27±1.54 x-z |
| Badami Zarand | Control | 1.15±0.02 j-l | 0.38±0.008 e-h | 0.77±0.008 g | 54.86±1.32 h-l |
| | A | 1.15±0.02 j-l | 0.39±0.01 e-g | 0.76±0.01 g-h | 54.80±1.47 i-l |
| | B | 1.10±0.02 l-p | 0.37±0.01 f-i | 0.73±0.01 g-l | 52.89±0.70 l-m |
| | C | 0.93±0.01 u-v | 0.30±0.01 m-p | 0.63±0.01 p-q | 49.39±1.53 n-p |
| | D | 0.73±0.02 y-z | 0.20±0.01 t | 0.53±0.01 t | 45.55±1.19 r-t |
| Fandoghi 48 | Control | 1.23±0.02 f | 0.41±0.03 e | 0.83±0.01 e | 56.88-i±1.16 g |
| | A | 1.23±0.02 f | 0.40±0.02 e-f | 0.83±0.01 e | 56.00±1.22 g-k |
| | B | 1.16 ±0.009h-j | 0.36±0.01 f-i | 0.80±0.01 e-f | 51.67±1.32 m-n |
| | C | 1.02±0.03 s | 0.32±0.01 k-n | 0.70±0.01 j-l | 47.22±1.48 p-r |
| | D | 0.73±0.02 y-z | 0.25±0.01 r-s | 0.49±0.01 u-v | 40.00±1.87 y-z |
| Sabs Pesteh Togh | Control | 1.19±0.03 g-i | 0.44±0.05 d | 0.74±0.02 h-j | 50.36±1.14 n-o |
| | A | 1.16±0.02 i-k | 0.44±0.02 d | 0.73±0.007 i-j | 46.93±7.47 o-r |
| | B | 1.05±0.02 q-s | 0.35±0.01 h-k | 0.70±0.009 j-l | 46.77±1.28 q-s |
| | C | 0.81±0.008 x | 0.28±0.02 o-q | 0.53±0.01 t | 42.47±0.90 v-y |
| | D | 0.58±0.01 a/ | 0.21±0.01 t | 0.36±0.005 x | 36.92±1.03 a/ |
| Ahmad Aghaee | Control | 1.04±0.01 q-s | 0.37±0.01 f-i | 0.67±0.007 m-o | 46.48±3.78 q-t |
| | A | 1.02±0.02 s | 0.35±0.01 h-k | 0.67±0.007 m-o | 44.15±0.22 s-v |
| | B | 0.97±0.01 t | 0.32±0.009 k-n | 0.64±0.006 o-q | 41.37±0.44 w-z |
| | C | 0.83±0.01 x | 0.29±0.01 n-q | 0.53±0.01 t | 36.60±0.30 a/ |
| | D | 0.62±0.01 a/ | 0.23±0.01 s-t | 0.39±0.01 w | 31.23±0.75 b/ |
| Rezaie Zodres | Control | 1.12±0.02 l-n | 0.36±0.008 g-j | 0.76±0.02 g-h | 57.72±1.04 e-g |
| | A | 1.11±0.02 m-n | 0.37±0.01 f-i | 0.75±0.01 g-i | 56.01±0.84 g-k |
| | B | 1.02±0.02 s | 0.32±0.01 k-m | 0.70±0.01 j-l | 53.25±1.63 lm |
| | C | 0.86±0.02 w | 0.29±0.01 n-q | 0.57±0.01 s | 48.56±1.41 o-q |
| | D | 0.58±0.03 a/ | 0.21±0.005 t | 0.37±0.02 w-x | 40.24±1.61 x-z |
| Shahpasand | Control | 1.54±0.007 a | 0.50±0.008 a-b | 1.04±0.007 a | 65.52±1.16 a |
| | A | 1.54±0.01 a | 0.50±0.01 a-b | 1.03±0.009 a-b | 64.52±1.19 a-b |
| | B | 1.50±0.03 a-b | 0.48±0.02 b-c | 1.02±0.008 a-b | 62.57±0.99 a-c |
| | C | 1.33±0.03 e | 0.40±0.02 e-f | 0.93±0.01 c | 59.98±0.79 d-f |
| | D | 1.10±0.02 m-o | 0.29±0.02 n-q | 0.81±0.01 e-f | 55.35±1.35 g-l |

Means in each column and for each factor, followed by similar letter(s) are not significantly different at the 1% probability level, using Duncan's Multiple Range Test.

Table 9 - Effect of interaction between salinity and cultivar on the physiologic traits measured

| Cultivar | Treatments | Cell membrane injury (%) | Relative ionic leakage (%) | Relative water content (%) |
|---|---|---|---|---|
| Khanjari | Control | - | 37.70±0.010 m-o | 85.25±0.64 a |
| | A | 2.98±1.28 w-y | 39.14±0.008 k-o | 84.16±0.46 a-b |
| | B | 8.09±0.91 t-u | 44.34±0.005 i-o | 81.31±0.51 b |
| | C | 23.09±3.10 k-m | 51.75±0.019 d-k | 77.60±0.62 c |
| | D | 46.47±0.70 b | 64.42±0.004 a-c | 70.36±1.04 f |
| Akbari | Control | - | 38.05±0.007 l-o | 85.08±0.40 a |
| | A | 0.83±1.21 x-y | 38.41±0.016 l-o | 84.52±0.60 a-b |
| | B | 5.27±1.07 u-w | 42.30±0.006 j-o | 82.90±0.60 a-b |
| | C | 16.37±1.78 o-q | 45.96±0.011 g-o | 82.08±0.68 a-b |
| | D | 27.83±2.18 h-i | 50.09±0.013 d-k | 80.22±0.56 b |
| Ghazvini | Control | - | 35.62±0.013 o | 83.19±0.57 a-b |
| | A | 0.42±0.19 y | 36.59±0.006 m-o | 82.98±0.64 a-b |
| | B | 2.67±2.28 x-y | 38.37±0.014 l-o | 81.58±0.42 b |
| | C | 5.89±2.81 u-w | 39.73±0.018 k-o | 80.88±0.36 b |
| | D | 16.17±0.62 o-q | 45.50±0.16 g-o | 78.95±0.45 b-c |
| Italiaie | Control | - | 40.85±0.012 j-o | 84.43±0.35 a-b |
| | A | 0.75±0.79 x-y | 40.88±0.005 j-o | 84.21±0.38 a-b |
| | B | 12.16±3.06 r-s | 47.75±0.018 e-n | 81.51±0.36 b |
| | C | 22.24±2.62 l-m | 52.75±0.015 c-i | 78.40±0.37 c |
| | D | 33.65±3.51 j-l | 60.54±0.020 a-d | 74.06±0.50 d-e |
| Kaleh Ghochi | Control | - | 39.43±0.015 k-o | 83.41±0.32 a-b |
| | A | 3.89±2.81 v-y | 40.81±0.017 k-o | 82.41±0.29 a-b |
| | B | 11.97±0.59 r-s | 43.67±0.003 i-o | 81.45±0.32 b |
| | C | 21.88±1.09 l-n | 48.89±0.006 d-l | 78.35±0.33 c |
| | D | 38.43±2.46 de | 59.29±0.015 b-f | 73.59±0.30 e |
| Jandaghi | Control | - | 37.68±0.015 m-o | 82.57±0.32 a-b |
| | A | 3.06±1.36 w-y | 38.85±0.008 l-o | 81.45±0.34 b |
| | B | 10.47±1.29 s-t | 45.53±0.008 h-o | 79.35±0.25 b-c |
| | C | 18.68±2.28 n-p | 55.70±0.014 b-i | 74.67±0.29 d-e |
| | D | 31.21±3.47 g-h | 66.61±0.021 a-b | 67.38±0.41 g |
| Mousa Abadi | Control | - | 37.59±0.007 l-o | 80.42±0.27 b |
| | A | 4.47±1.83 u-x | 39.39±0.011 k-o | 79.53±0.28 b-c |
| | B | 18.68±2.77 n-p | 49.41±0.017 d-k | 75.55±0.35 d |
| | C | 33.47±2.27 f-g | 57.80±0.014 b-g | 70.52±0.66 f |
| | D | 54.83±4.50 a | 71.34±0.028 a | 64.17±0.52 i |
| Ebrahimi | Control | - | 40.04±0.010 k-o | 81.51±0.25 b |
| | A | 4.88±4.12 u-w | 42.77±0.027 j-o | 80.40±0.45 b-c |
| | B | 12.92±4.01 q-s | 46.57±0.024 f-o | 78.49±0.31 b-c |
| | C | 18.34±2.62 n-p | 49.90±0.016 d-l | 76.34±0.34 c-d |
| | D | 27.70±4.05 h-i | 56.65±0.024 b-h | 69.95±0.45 f-g |
| Badami Zarand | Control | - | 35.90±0.018 n-o | 80.56±0.26 b-c |
| | A | 2.36±3.55 w-y | 37.60±0.028 l-o | 79.41±0.24 b-c |
| | B | 6.96±2.50 t-v | 41.66±0.016 j-o | 78.13±0.30 c |
| | C | 14.18±2.66 q-r | 45.00±0.017 h-o | 76.38±0.32 c-d |
| | D | 21.21±2.04 l-n | 49.51±0.013 d-l | 73.21±0.47 e |
| Fandoghi 48 | Control | - | 41.44±0.012 j-o | 82.51±0.33 a-b |
| | A | 4.18±3.07 v-y | 43.52±0.022 j-o | 81.64±0.30 b |
| | B | 10.24±2.12 s-t | 47.33±0.012 f-o | 79.22±0.47 b-c |
| | C | 26.48±4.68 i-k | 56.86±0.027 b-h | 75.25±0.54 d |
| | D | 41.04±3.79 c-d | 65.40±0.022 a-b | 69.12±0.47 f-g |
| Sabs Pesteh Togh | Control | - | 41.06±0.014 j-o | 81.34±0.31 b |
| | A | 5.35±3.95 u-w | 44.64±0.029 h-o | 79.60±0.41 b-c |
| | B | 14.57±6.87 q-r | 50.94±0.039 d-k | 77.18±0.32 c-d |
| | C | 28.48±4.47 h-i | 57.93±0.025 b-g | 73.67±0.59 e |
| | D | 42.89±6.21 c | 66.20±0.035 a-b | 66.49±0.77 g-i |
| Ahmad Aghaee | Control | - | 39.50±0.013 k-o | 85.02±0.32 a |
| | A | 3.27±1.44 v-y | 41.35±0.008 j-o | 84.39±0.36 a-b |
| | B | 9.63±0.93 s-t | 44.05±0.005 i-o | 83.26±0.42 a-b |
| | C | 19.71±1.64 m-o | 50.30±0.010 d-j | 80.1±0.38 b |
| | D | 35.57±2.85 e-f | 60.11±0.017 a-e | 75.38±0.38 d |
| Rezaie Zodres | Control | - | 40.12±0.006 k-o | 81.05±0.42 b |
| | A | 2.18±1.61 w-y | 40.97±0.010 j-o | 80.50±0.25 b-c |
| | B | 10.48±1.51 s-t | 48.81±0.009 d-l | 77.17±0.51 c-d |
| | C | 26.78±3.43 i-j | 55.85±0.020 b-i | 74.34±0.45 d-e |
| | D | 47.45±2.95 b | 68.31±0.017 a-b | 66.95±0.57 g-i |
| Shahpasand | Control | - | 39.92±0.006 k-o | 79.83±0.47 b-c |
| | A | 3.61±3.10 v-y | 40.43±0.021 k-o | 79.49±0.22 b-c |
| | B | 5.98±1.87 u-w | 42.63±0.011 j-o | 78.89±0.51 b-c |
| | C | 15.32±3.43 p-r | 46.68±0.020 f-o | 77.15±0.53 c |
| | D | 27.77±2.98 h-i | 53.23±0.018 c-j | 74.41±0.39 d-e |

Means in each column and for each factor, followed by similar letter(s) are not significantly different at the 1% probability level, using Duncan's Multiple Range Test.

was observed the least decrease in the relative humidity content of the leaves.

Relative ion leakage percentage in all studied cultivars was increased by increasing salinity concentration. The increase in the relative ion leakage percentage was significant between the studied cultivars. The highest relative ion leakage percentage was observed in Mousa Abadi cultivar in salinity level D. After this cultivar, Rezai Zod Res, Jandaghi, Sabz Pesteh Togh, Fndoghi 48, Kanjari and Italiyayi cultivars had the highest relative ion leakage percentage. The increase in relative ion leakage percentage was not significant in Ghazvini cultivar compared to the control plants (Table 9). The results showed that the cultivars had a significant difference in cell membrane injury percentage. The highest cell membrane injury percentage was observed in the leaves of Mousa Abadi (54.83±4.50%), and the lowest cell membrane injury percentage was observed in the leaves of Ghazvini (16.17±0.62%).

Results reported in Table 10 assessed that with increasing salinity concentration in irrigation water, the sodium concentration in the leaves and roots of total cultivars increased. The increase in sodium concentration in the leaves of Ghazvini cultivar was only significant when plants were treated with salinity level D, while in Akbari, Badami Zarand and Shahpasand cultivars was observed a significant increased when treated with salinity levels C and D, compared to the control plants. While the increase of sodium concentration in the leaves of other cultivars was significant different salinity levels B, C and D, compared to the control plants (Table 10). The highest sodium concentration in leaves was observed in the salinity level D and in Mousa Abadi (2.09±0.045%), Rezaie Zood Res (2.05±0.030%), Khanjari (2.03±0.115%) and Jandaghi (1.90±0.035%) cultivars treated. Also the highest sodium concentration in roots was also observed in salinity level D, and in Mousa Abadi (3.04±0.06%) and Rezaie Zood Res (2.99±0.05%) cultivars.

With increasing salinity levels (to 14.75 dS/m), potassium concentration increased in leaves and roots of Akbari, Ghazvini, Shahpasand, Badami Zarand and Ebrahimi cultivars while potassium content in the leaves and roots of other cultivars except Mousa Abadi and Rezaie Zood Res increased to salinity level C. Potassium content in the leaves and roots of Mousa Abadi and Rezaie Zood Res cultivars was increased only in salinity level B. Overall, the highest potassium content in leaves and roots was observed in salinity level C and in Ghazvini (1.81±0.02%) and Akbari (1.38±0.02%) cultivars.

## 4. Discussion and Conclusions

Based on the results of this study, with increasing salinity concentration in irrigation water, final height, trunk diameter and number of leaves in all studied cultivars decreased. Plant height is heavily dependent on growth environment. Since the growth phenomenon gained vital activities in which condition the plant must be in possession of enough water, reduction in the height occurs in case of failure to provide the required water due to the reduction of cell turgor pressure and length of the cells would be negatively affected (Munns, 2002; Munns and Tester, 2008). The osmotic effects of salinity stress can be observed immediately after salt application and are believed to continue for the duration of exposure, resulting in inhibited cell expansion and cell division (Munns 2002; Munns and Tester, 2008). In this research, trunk diameter and its growth were decreased during the application of salinity stress in all cultivars. These results are consistent with other results (Sepaskhah and Maftoun, 1988; Munns and Tester, 2008; Zrig *et al*., 2015). It has been reported that growth rates of pistachio trees decrease with increasing sodium chloride (NaCl) concentration in soil. It has been also reported that there is a positive correlation between sodium ($Na^+$) as well as chloride ($Cl^-$) concentration in plant tissue and soil (Sepaskhah and Maftoun, 1988; Munns and Tester, 2008; Zrig *et al*., 2015). Based on the results of this study, number of leaves with increasing salinity concentrations reduced. Our results are consistent with studies reporting that increasing salinity levels negatively affect morphology and number of leaves in pistachio trees (Picchioni and Myamoto, 1990; Saadatmand *et al*., 2007; Karimi *et al*., 2011). The results of this research showed that with increasing salinity, percentage of green leaves, leaves and shoots fresh and dry weights in all cultivars decreased but the percentage of necrotic leaves and percentage of downfall leaves increades. The cultivars showed different responses to salinity levels. These results are consistent with the results of Karimi *et al.* (2009 and 2011). In these studies, effect of salinity levels on pistachio cultivars was investigated and was reported that pistachio cultivars showed different responses to salinity levels. Although pistachio trees are classified as tolerant to salinity, but amount of their tolerance to salinity is differently (Sepaskhah and Maftoun, 1988;

Table 10 - Effect of interaction between salinity and cultivar on root and leaf $K^+$ and $Na^+$ contents

| Cultivar | Treatments | Root $Na^+$ (%) | Leaf $Na^+$ (%) | Root $K^+$ (%) | Leaf $K^+$ (%) |
|---|---|---|---|---|---|
| Khanjari | Control | 0.55±0.03 s-y | 0.43±0.027 q-v | 0.60±0.03 z-a′ | 1.35±0.03 k-m |
| | A | 0.59±0.01 q-y | 0.46±0.023 q-v | 0.76±0.05 p-w | 1.44±0.11 d-i |
| | B | 0.70±0.06 o-x | 0.64±0.023 m-r | 0.73±0.05 q-y | 1.56±0.03 c-f |
| | C | 1.57±0.11 g-i | 1.25±0.055 g-h | 0.50±0.04 b′ | 1.30±0.06 i-o |
| | D | 2.59±0.06 c-d | 2.03±0.116 a | 0.37±0.04 d′ | 1.01±0.04 u-x |
| Akbari | Control | 0.42±0.01 y | 0.37±0.013 t-v | 0.80±0.03 m-u | 1.08±0.03 r-x |
| | A | 0.44±0.008 x-y | 0.39±0.005 t-v | 0.99±0.03 f-i | 1.21±0.05 m-r |
| | B | 0.48±0.03 v-y | 0.42±0.007 r-v | 1.37±0.03 a | 1.58±0.04 c-e |
| | C | 0.97±0.03 l-n | 0.73±0.035 k-n | 1.38±0.02 a | 1.59±0.02 b-d |
| | D | 1.86±0.04 f | 1.40±0.066 e-g | 0.77±0.02 o-v | 1.11±0.03 q-v |
| Ghazvini | Control | 0.46±0.003 w-y | 0.41±0.014 s-v | 0.79±0.02 n-v | 1.31±0.02 i-n |
| | A | 0.47±0.004 w-y | 0.41±0.007 s-v | 0.84±0.02 k-r | 1.48±0.02 d-h |
| | B | 0.49±0.006 v-y | 0.43±0.004 q-v | 0.95±0.02 g-k | 1.55±0.03 c-g |
| | C | 0.52±0.006 u-y | 0.46±0.007 q-v | 1.08±0.02 d-f | 1.81±0.02 a |
| | D | 1.05±0.02 k-m | 0.82±0.023 k-m | 0.85±0.02 j-q | 1.35±0.02 h-m |
| Italiaie | Control | 0.57±0.02 r-y | 0.34±0.006 v | 0.93±0.02 h-l | 1.08±0.02 r-x |
| | A | 0.61±0.01 q-y | 0.36±0.007 t-v | 0.98±0.03 f-i | 1.19±0.02 n-t |
| | B | 0.78±0.03 n-t | 0.43±0.007 q-v | 1.13±0.02 cd | 1.23±0.02 m-p |
| | C | 1.21±0.02 j-k | 0.82±0.027 k-m | 0.88±0.02 i-p | 0.99±0.02 v-x |
| | D | 1.81±0.04 f | 1.55±0.035 c-e | 0.60±0.02 z-a′ | 0.67±0.02 a′ |
| Kaleh Ghochi | Control | 0.67±0.03 p-y | 0.45±0.005 q-v | 0.89±0.02 h-o | 1.10±0.02 r-w |
| | A | 0.70±0.02 o-x | 0.47±0.003 p-v | 0.95±0.02 g-k | 1.18±0.04 n-t |
| | B | 0.75±0.009 n-u | 0.49± 0.003 p-v | 1.14±0.02 b-d | 1.57±0.02 c-e |
| | C | 1.38±0.02 i-j | 0.76±0.029 k-n | 1.11±0.02 de | 1.55±0.02 c-g |
| | D | 2.55±0.04 d | 1.50±0.044 d-f | 0.82±0.02 l-t | 1.17±0.02 n-t |
| Jandaghi | Control | 0.49±0.006 u-y | 0.41±0.005 s-v | 0.68±0.02 u-z | 0.82±0.02 y-z |
| | A | 0.60±0.005 q-y | 0.46±0.004 q-v | 0.72±0.03 r-z | 0.93±0.02 x-y |
| | B | 0.82±0.01 m-q | 0.57±0.017 n-u | 0.75±0.05 q-x | 1.08±0.02 r-w |
| | C | 1.52±0.02 g-i | 1.22±0.035 g-h | 0.69±0.02 u-z | 0.71±0.02 z-a′ |
| | D | 2.73±0.03 cd | 1.90±0.035 a-b | 0.35±0.03 d′ | 0.46±0.02 b′ |
| Mousa Abadi | Control | 0.53±0.007 t-y | 0.44±0.002 q-v | 0.60′±0.01 z-a | 1.05±0.02 s-x |
| | A | 0.65±0.01 q-y | 0.47±0.005 p-v | 0.85±0.02 j-q | 1.13±0.02 p-v |
| | B | 0.83±0.03 m-p | 0.71±0.034 l-o | 0.63±0.02 a′ | 1.07±0.02 r-x |
| | C | 1.76±0.02 f-g | 1.33±0.027 f-h | 0.45±0.02 c′ | 0.95±0.02 w-y |
| | D | 3.04±0.06 a | 2.09±0.045 a | 0.34±0.01 d′ | 0.40±0.02 c′ |
| Ebrahimi | Control | 0.46±0.005 w-y | 0.39±0.005 t-v | 0.68±0.02 u-z | 1.26±0.03 k-q |
| | A | 0.48±0.005 v-y | 0.41±0.004 s-v | 0.77±0.02 o-v | 1.37±0.02 h-l |
| | B | 0.53±0.007 t-y | 0.45±0.006 q-v | 0.82±0.02 l-t | 1.48±0.02 d-h |
| | C | 1.14±0.04 k-l | 0.87±0.020 j-l | 0.83±0.02 k-s | 1.50±0.02 d-h |
| | D | 2.11±0.03 e | 1.62±0.027 c-d | 0.60±0.02 z-a′ | 1.15±0.01 o-u |
| Badami Zarand | Control | 0.51±0.007 u-y | 0.48±0.005 p-v | 0.71±0.02 s-z | 1.04±0.01 t-x |
| | A | 0.53±0.003 t-y | 0.49±0.004 p-v | 0.74±0.02 q-y | 1.16±0.02 n-u |
| | B | 0.56±0.008 r-y | 0.51±0.019 o-v | 0.97±0.02 f-j | 1.43±0.01 e-j |
| | C | 0.83±0.02 m-q | 0.64±0.027 m-r | 1.01±0.01 e-h | 1.47±0.01 d-h |
| | D | 1.73±0.04 f-g | 1.23±0.027 g-h | 0.70±0.02 t-z | 1.05±0.01 s-x |
| Fandoghi 48 | Control | 0.60±0.006 q-y | 0.42±0.002 r-v | 0.82±0.02 l-t | 1.19±0.02 n-t |
| | A | 0.64±0.008 q-y | 0.44±0.005 q-v | 0.91±0.02 h-n | 1.28±0.03 j-p |
| | B | 0.99±0.01 l-n | 0.79±1.21 k-m | 0.92±0.02 h-m | 1.35±0.10 h-m |
| | C | 1.43±0.02 h-j | 0.93±0.01 j-k | 0.90±0.02 h-n | 1.30±0.02 i-o |
| | D | 2.74±0.04 c-d | 1.73±0.04 b-c | 0.64±0.02 x-z | 1.01±0.02 u-x |
| Sabs Pesteh Togh | Control | 0.60±0.007 q-y | 0.48±0.005 p-v | 0.62±0.09 y-z | 1.07±0.02 r-x |
| | A | 0.64±0.01 q-y | 0.51±0.005 o-v | 0.88±0.01 i-p | 1.28±0.02 j-p |
| | B | 0.79±0.04 n-s | 0.57±0.02 n-u | 1.01±0.02 e-h | 1.44±0.02 d-i |
| | C | 1.55±0.03 g-i | 1.02±0.05 i-j | 0.67±0.009 v-z | 1.19±0.01 n-t |
| | D | 2.81±0.07 b-c | 1.83±0.06 b | 0.44±0.01 c′ | 0.83±0.01 y-z |
| Ahmad Aghaee | Control | 0.62±0.006 q-y | 0.55±0.004 n-v | 0.95±0.02 g-k | 1.37±0.02 h-l |
| | A | 0.65±0.006 q-y | 0.58±0.005 n-t | 1.08±0.02 d-f | 1.54±0.03 c-g |
| | B | 0.81±0.02 n-p | 0.63±0.02 m-s | 1.39±0.02 a | 1.65±0.03 b-c |
| | C | 1.64±0.02 f-h | 1.17±0.02 h-i | 1.35±0.01 a | 1.50±0.05 d-h |
| | D | 2.60±0.03 c-d | 1.83±0.04 b | 0.64±0.01 w-z | 1.17±0.02 n-t |
| Rezaie Zodres | Control | 0.55±1.41 s-y | 0.42±0.005 r-v | 0.82±0.02 l-t | 1.22±0.02 l-r |
| | A | 0.60±0.008 q-y | 0.45±0.005 q-v | 1.08±0.02 d-f | 1.41±0.02 f-k |
| | B | 0.93±0.02 l-o | 0.68±0.03 l-p | 0.85±0.01 j-q | 1.21±0.02 m-r |
| | C | 1.74±0.03 f-g | 1.31±0.02 f-h | 0.62±0.03 y-z | 0.98±0.03 v-x |
| | D | 2.99±0.05 a-b | 2.05±0.03 a | 0.39±0.02 d′ | 0.64±0.02 a′ |
| Shahpasand | Control | 0.43±0.004 y | 0.35±0.005 u-v | 0.97±0.02 f-j | 1.40±0.03 g-k |
| | A | 0.45±0.003 x-y | 0.36±0.004 t-v | 1.05±0.01 d-g | 1.48±0.02 d-h |
| | B | 0.48±0.006 v-y | 0.38±0.006 t-v | 1.23±0.01 b-c | 1.68±0.03 a-c |
| | C | 0.91±0.02 l-p | 0.65±0.02 m-q | 1.24±0.02 b | 1.72±0.03 a-b |
| | D | 1.76±0.02 f-g | 1.28±0.07 g-h | 0.90±0.03 h-n | 1.37±0.03 h-l |

Means in each column and for each factor, followed by similar letter(s) are not significantly different at the 1% probability level, using Duncan's Multiple Range Test.

Munns and Tester, 2008).

Based on the results of this study, $F_v/F_m$ ratio was 0.83±1 in the leaves of the control plants indicating the existence of ideal and non-stressed environmental conditions for the growth of all cultivars throughout the experimental period. In many plant species, when $F_v/F_m$ ratio is about 0.83, it means that stress hasn't been introduced to the plant and, lower levels indicate stress condition in plants (Maxwell and Johnson, 2000). Regarding changes in $F_v/F_m$ values the stress intensity in Rezaie Zood Res and Mousa Abadi cultivars were more severe than other cultivars (0.59±0.015 and 0.61±0.09, respectively). On the contrary, Gazvini and Akbari cultivars were less damaged (0.76±0.003 and 0.75±0.007, respectively). These results are consistent with the results of (Herda *et al*., 1999; Starck *et al*., 2000; DeEll and Toivonen, 2003; Kodad *et al*., 2010). It has been reported that salinity stress is one of the most important environmental factors limiting photosynthesis. Symptoms of salinity stress are expressed at both stomatal and non-stomatal levels. At stomatal level, the plant closes its stomata to prevent injuries (Maxwell and Johnson, 2000, Ranjbarfordoei *et al*., 2006). As a result, net photosynthesis is unavoidably reduced due to a decrease in $CO_2$ availability, which potentially damages the photosynthetic apparatus (Lawlor and Cornic, 2002). Most of the decrease in photon flux energy used for photochemistry can be explained as an increase in non-photochemical dissipation of excitation energy (Lawlor and Cornic, 2002).

The results of this research indicated that under salinity stress amount of chlorophyll b was reduced more than amount of chlorophyll a. These results are consistent with the results of Dejampour *et al.* (2012). These researchers investigated the effect of NaCl on the amount of chlorophyll a, b and total chlorophyll in some of the *Prunus* genus, and they reported that amount of chlorophyll b and total chlorophyll significantly decreased under salinity stress. However, reduction in amount of chlorophyll a in these plants was not significant. Also, total chlorophyll content was decreased significantly in all studied cultivars with increasing salinity that are consistent with the results of Karimi *et al.* (2009 and 2011). Researcher reported that salinity stress leads to reduction chlorophyll content and photosynthesis capacity in plants which are the major reasons of decreases growth and yield in plants (Levitt, 1980; Munns, 2002; Munns and Tester, 2008).

The results showed that content of relative humidity were decreased significantly as the salinity increased. The highest reduction in relative humidity content was observed in leaves Mousa Abadi, Rezaie Zood Res and Sabz Pesteh Togh cultivars under salinity level of 19.8 dS/m. The results are consistent with the data reported by Shibli *et al*. (2000) and Massai *et al*. (2004). Salinity, through the gradual accumulation of sodium ions, reduces the relative water content and osmotic potential of the leaf in full turgor state. Relative ion leakage percentage and cell membrane injury percentage in all studied cultivars were increased by increasing salinity concentration. The highest relative ion leakage percentage and cell membrane injury percentage were observed in Mousa Abadi cultivar under treatment 19.8 dS/m. These results are consistent with the results of other studies. It has been reported that using a relative ionic leak test is one way to find out the extent to which cell membranes are damaged. Recording the relative ion leakage rate allow for tissue damage estimation. This method was used for the first time by Dexter *et al*. (1930 and 1932) to investigate the resistance to cold in plants and, over time, was used to measure cell membrane damage in relation to other environmental stresses, including salinity stress (Chen *et al*., 1999).

With increasing salinity concentration in irrigation water, the sodium concentration in the leaves and roots of total cultivars studied increased. The highest sodium concentration in leaves and roots were observed in salinity level 19.8 dS/m and in Mousa Abadi and Rezaie Zood Res cultivars which had the highest percentage of leaves necrosis and loss, and at the end of the experiment, only 52.47±4.98% and 53.48±4.82% of leaves were greens. In researches on various plants under salt stress, it has been reported that the loss of water availability, toxicity of $Na^+$ and ion imbalance leads to growth limitation in plants (Mahajan and Tuteja, 2005; Szczerba *et al*., 2009). It is repeatedly reported that $K^+$ deficiency and $Na^+$ toxicity are major restrictors of crop production worldwide (Mahajan and Tuteja, 2005; Szczerba *et al*., 2008, 2009). The results indicated that the type of cultivar is effective in potassium absorption and its transmission to the aerial part. In this research, Ghazvini and Akbari cultivars with increasing the amount of potassium in its leaves and roots could reduce the negative and destructive effects of sodium better than other cultivars. Potassium plays an important role in vital metabolites in salinity stress conditions, so that the $K^+$ can counteract $Na^+$ stresses, thus the potential of plants to tolerate salinity is strongly dependent on their potassium nutrition

(Aleman *et al*., 2011; Nieves *et al*., 2016).

Generally, the results of this study showed that by applying salinity stress and increasing its concentration, growth indices including branch height, branch diameter, number of total leaves, percentage of green leaves, fresh and dry weight of leaves, shoots and roots, relative humidity content, chlorophyll a, chlorophyll b and total chlorophyll content, have been reduced in the all cultivars studied. But the percentage of necrotic leaves, percentage of downfall leaves, relative ionic percentage and cell membrane injury percentage were increased. However, the reduction and increase of measured traits were significantly different among studied cultivars. The results also showed that salinity stress affected the young trees through increasing the amount of minimum fluorescence ($F_0$) and decreasing the maximum fluorescence ($F_m$) and reducing variable fluorescence ($F_v$) as well as $F_v/F_m$ ratio from 0.83±1 in the control plants to 0.59±0.015 in Rezaie Zood Res and 0.61±0.009 in Mousa Abadi cultivar. Based on the results mentioned above, reducing $F_v/F_m$ ratio was symptoms of the damaging stress in plants. The results of method chlorophyll fluorescence in this research are consistent with the results of morphological and physiological traits and therefore, it can be said that chlorophyll fluorescence technique ($F_v/F_m$ indicator) is a rapid, sensitive and non-destructive method to check the intensity of stress that induced to plants. Overall, the result showed that type of cultivar and level of salinity was affected on concentration of $Na^+$ and $K^+$ in leaves and roots. Ghazvini cultivar was recognized as the most tolerant cultivar to salinity. This cultivar could tolerate salinity 14.75 dS/m. After this cultivar, Akbari, Badami Zarand and Shahpasand cultivars had more tolerance to salinity, respectively. In contrast, Rezaie Zood Res and Mousa Abadi cultivars were recognized as the most sensitive cultivars to salinity stress. After these cultivars, Khanjari, Jandaghi and Fndoghi 48 cultivars had more sensitive to salinity.

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